2.5 The Electrolytic Cell

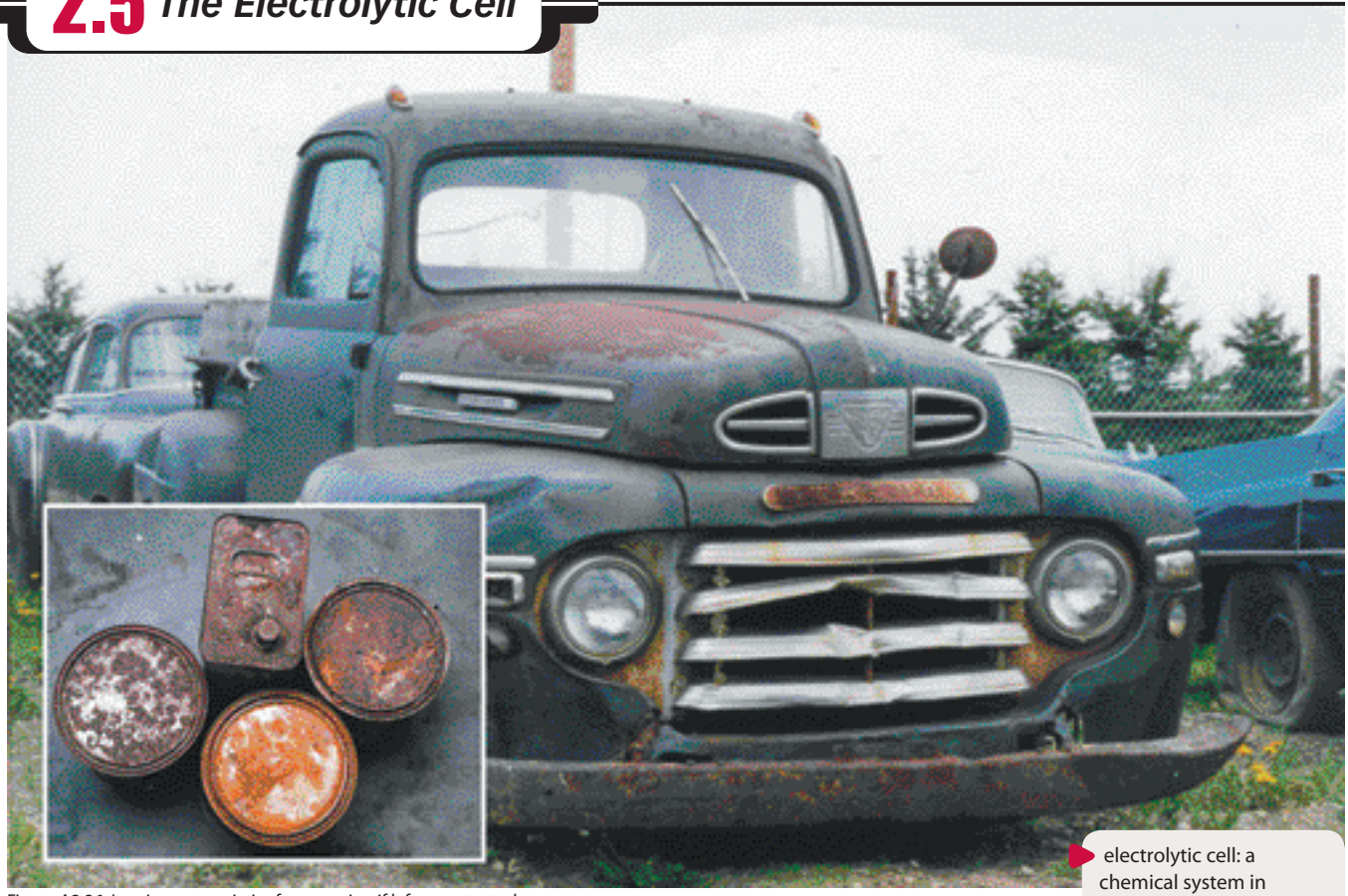


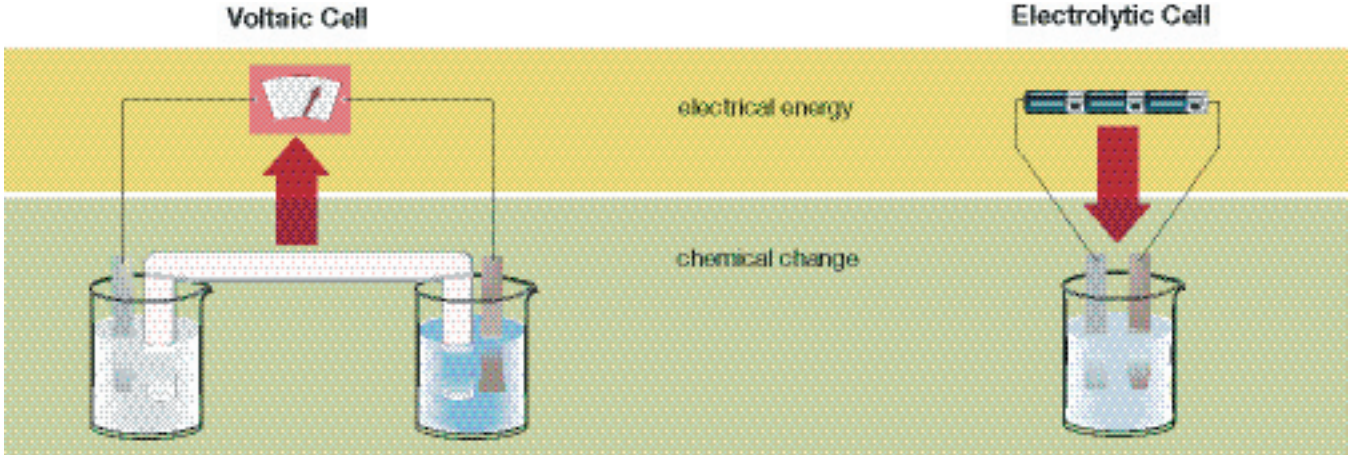
Figure A2.26: Iron is an easy victim for corrosion if left unprotected.

electrolytic cell: a chemical system in which non-spontaneous oxidation and reduction reactions are made to occur by the application of electrical energy

You use metals every day. However, most metals are reactive and will oxidize to produce metal ions. With this reaction, they will eventually return to the earth, combining with other substances to reform the ionic compounds from which they came.

As indicated by their position in the activity series, gold and silver are two metals that do not oxidize as easily as other metals. This makes them extremely valuable because objects made from these metals will resist corrosion and probably last a long time. Unfortunately, it is usually too expensive to make an object entirely of these precious metals.

A cost-effective alternative is to apply a very thin coating of a corrosion-resistant metal to the surface of a susceptible metal. These protective coatings are applied using a variation of the voltaic cell called the **electrolytic cell**. Both cells involve chemical change and electrical energy.



The difference between these cells is that a voltaic cell uses chemical change to produce electrical energy, whereas an electrolytic cell uses electrical energy to produce a chemical change.

You can observe a very simple electrolytic cell in operation in the next activity.

Try This Activity

Using Electrical Energy to Force Chemical Change

Purpose

You will observe the effect of an electric current through water. A small amount of sodium sulfate is added to the water as an electrolyte to improve its ability to conduct electricity.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Materials

- 500-mL beaker
- 9-V battery
- matches
- wood splints
- stirring rod
- 28.0 g of sodium sulfate, $Na_2SO_4(s)$
- 400 mL of distilled water
- 2 test tubes (15 mm ¥ 150 mm)
- test tube rack

CAUTION!

Use gloves, safety glasses, and a lab apron for this activity.

Procedure

step 1: Add 28.0 g of sodium sulfate, $Na_2SO_4(s)$, into a beaker containing 400 mL of water, and stir to dissolve the solute.

step 2: Once the sodium sulfate has dissolved, fill each test tube to the very top with the solution and place it in a test tube rack.

step 3: Place a new 9-V battery into the remaining solution in the beaker. The battery should be sitting on the bottom of the beaker, completely submerged in the solution, with the terminals facing upward.

step 4: Observe each terminal of the battery for evidence of chemical change. You should see some gas bubbles appearing at each terminal. Can you predict the gases that are produced?

step 5: To collect the gas produced at each terminal, take the two test tubes filled with the electrolyte solution and cover the tops with your thumbs. Carefully tip the test tubes over, and slowly remove your thumb once they are under the surface of the solution. Position each test tube so the opening covers one of the battery terminals.

step 6: After a few minutes, note whether one tube is filling with gas faster than the other.

step 7: Given that the chemical formula for water is $H_2O(l)$, determine which of the test tubes contains hydrogen gas and which contains oxygen gas.

step 8: Remove the test tube you think contains hydrogen gas. Do this by placing your thumb over the open end of the test tube and carefully removing each test tube without losing the gas collected. While pointing the open end of the test tube in a safe direction, use a burning splint to confirm your prediction.

step 9: Remove the test tube you think contains oxygen gas using the same method stated in step 8. While pointing the open end of the test tube in a safe direction, use a glowing splint to confirm your prediction in this case.

Analysis

1. In this activity, you assembled a simple electrolytic cell.
   a. Identify the source of electrical energy for this cell.
   b. Describe the evidence that indicates that this electrolytic cell caused a chemical change.
2. Consider the gas collected in the test tube positioned over the positive terminal of the battery. What does the splint test indicate about the identity of this gas?
3. Consider the gas collected in the test tube positioned over the negative terminal of the battery. What does the splint test indicate about the identity of this gas?
4. More gas accumulated in one of the test tubes than in the other. State the identity of this gas, and use the following chemical reaction to help you explain why a larger amount of it was produced.

   $2\ H_2O(l)$ Æ $2\ H_2(g) + O_2(g)$
5. In this activity you added a salt, sodium sulfate, to act as an electrolyte so that the distilled water could conduct electricity. Concisely explain why both voltaic and electrolytic cells require electrolytes to properly function.

Using Electrical Energy to Produce Metal Coatings

Many metal products manufactured today have a thin coating of a less corrosive metal added to their surface. In this process, the object to be coated is submerged in a solution containing metal ions that will eventually form the corrosion-resistant surface. An external source of electrical energy supplies energy to electrons that flow through two electrodes: one electrode connects to the object to be coated and the other to a second electrode in the conducting solution to complete the circuit. This process is called **electroplating**.

You will have an opportunity to build an electrolytic cell that can electroplate copper onto a carbon electrode in the next investigation.

electroplating: the process of depositing a metal at the cathode of an electrolytic cell

Figure A2.27: Large-scale industrial electroplating facilities use banks of electrolytic cells to produce metal coatings.

Investigation

Electroplating Copper

Purpose

You will assemble an electrolytic cell that will add a thin coating of copper to a carbon electrode. You will observe changes to the electrodes that will verify that chemical change has occurred.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Materials

- 150 mL of 0.250-mol/L copper(II) sulfate solution, $CuSO_4(aq)$
- 2 electrical leads with alligator clips
- 9-V battery (or direct current power supply)
- carbon electrode
- copper electrode
- 250-mL beaker
- electronic balance

CAUTION!

Use gloves, safety glasses, and a lab apron for this investigation. Copper(II) sulfate solution, $CuSO_4(aq)$, is toxic and an irritant.

CAUTION!

Proceed with caution if you are using a direct current power supply. An ammeter should be used to ensure that the current does not exceed 2.0 A. The power supply should be protected by a fuse or circuit breaker in case the electrodes accidentally touch.

Procedure

step 1: Before starting this investigation, carefully read over the entire investigation. Design a data table to record the qualitative and quantitative observations you will make during the investigation.

step 2: Pour 150 mL of 0.250-mol/L copper(II) sulfate solution into the beaker.

step 3: Measure the initial masses of the carbon and copper electrodes, and record each value in your data table.

step 4: Take the carbon electrode and attach an alligator clip to one of its ends. Take the other end of the alligator clip and attach it to the negative terminal of the 9-V battery (or to the negative terminal of the power supply).

step 5: Take the copper electrode and attach an alligator clip to one of its ends. Take the other end of the alligator clip and attach it to the positive terminal of the 9-V battery (or to the positive terminal of the power supply).

step 6: Carefully place the electrodes into the copper(II) sulfate solution. Do not immerse the alligator clips or let the electrodes touch each other.

step 7: Let the electrodes sit in the solution for approximately 10 min. During this time, look at the electrodes and note any changes you see.

step 8: Disconnect the alligator clips from the battery and the electrodes. Observe any changes to the electrodes that have occurred.

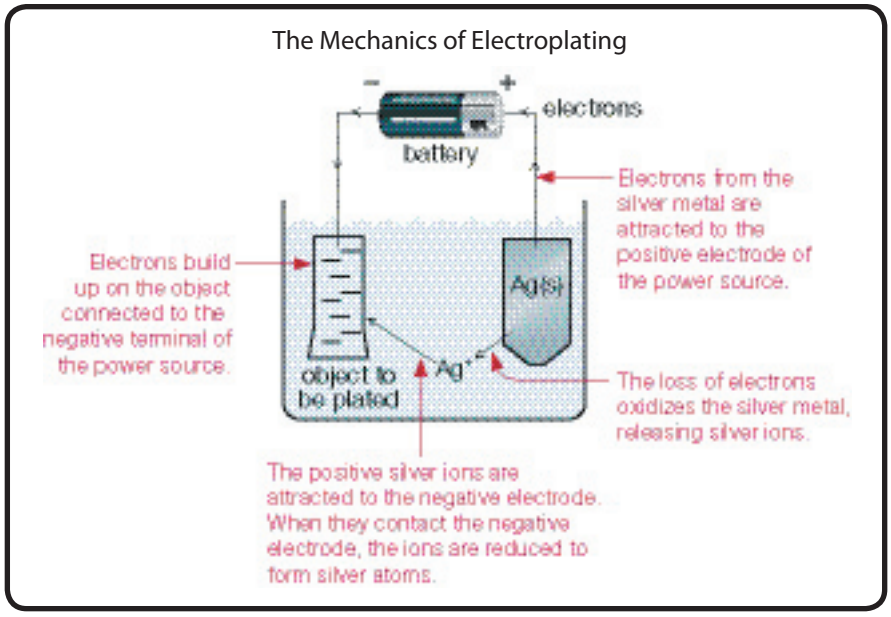
step 9: Allow the electrodes to dry thoroughly, and measure the final mass of each electrode. Record the values in your data table.

Analysis

1. Describe any changes that occurred at the carbon electrode.
2. Describe any changes that occurred at the copper electrode.
3. Identify the evidence that indicates a reduction half-reaction occurred during the operation of the electrolytic cell. Write the half-reaction that describes this reaction.
4. Identify the evidence that indicates an oxidation half-reaction occurred during the operation of the electrolytic cell. Write the half-reaction that describes this reaction.
5. Draw a diagram of the apparatus. Label the anode, the cathode, the electrolyte, and the direction of electron flow provided by the power source.

A Look into Electroplating—The Mechanics of an Electrolytic Cell

Earlier, you explored the idea that batteries make use of spontaneous oxidation and reduction reactions. Energy is released as relatively reactive metals lose electrons to relatively reactive ions. The resulting current of electrons is guided through a wire so that their energy can be captured and used by your electronic devices.


The Mechanics of Electroplating
−
+
electrons
battery
Electrons from the silver metal are attracted to the positive electrode of the power source.
Electrons build up on the object connected to the negative terminal of the power source.
Ag(s)
object to be plated
Ag+
The loss of electrons oxidizes the silver metal, releasing silver ions.
The positive silver ions are attracted to the negative electrode. When they contact the negative electrode, the ions are reduced to form silver atoms.

Electroplating, however, is a process that forces non-spontaneous oxidation and reduction reactions to occur. Energy is used to remove electrons from the metal located at the anode of the cell and transfer them to metal ions within the electrolyte near the cathode of the cell. The cell you constructed in the last activity forced copper(II) ions in the solution to gain electrons and become copper metal. Cells like this can be used to electroplate one metal over another metallic substance. Can you think of a reason why this process is an effective way to protect metals that tend to be easily oxidized?

Electroplating is commonly used to protect metals from other elements in the environment that might cause corrosion. Iron and other metals are often electroplated with chromium, platinum, silver, or gold to protect them from substances in the atmosphere that oxidize them. Electroplating a metal can increase the life span of the consumer good without having to actually make the entire object out of an expensive metal.

Practice

Use the following information to answer questions 44 to 46.

Gold Used in Jewellery

If an object is made entirely from pure gold, it is described as being made from 24-karat gold. However, because gold is such a soft metal, it is often combined with other metals, like brass (copper and zinc) and nickel, to make the object more durable. A piece of jewellery made from 18-karat gold is 75% pure gold, and a piece that is 12-karat gold is only 50% pure gold. By law, every piece of jewellery has to be stamped with the karat or (k) mark, along with the manufacturer's trademark.

Gold-filled jewellery is also called gold overlay or gold clad. These pieces have a layer of at least 10-karat gold that has been permanently welded to a less expensive metal underneath. The karat gold must make up at least 1/20 of the total mass of the piece in order to qualify as gold-filled. Gold-filled items, like designer frames for eyeglasses, have many of the advantages of a gold surface without the excessive weight characterized by 24-karat gold.

Jewellery that is gold-plated means that an electrolytic cell was used to coat the surface with a plating of at least 10-karat gold. The coating on the surface is much thinner than it is for rolled gold, so these pieces are not as durable. This process is ideal for pieces that have intricate designs or are very large.

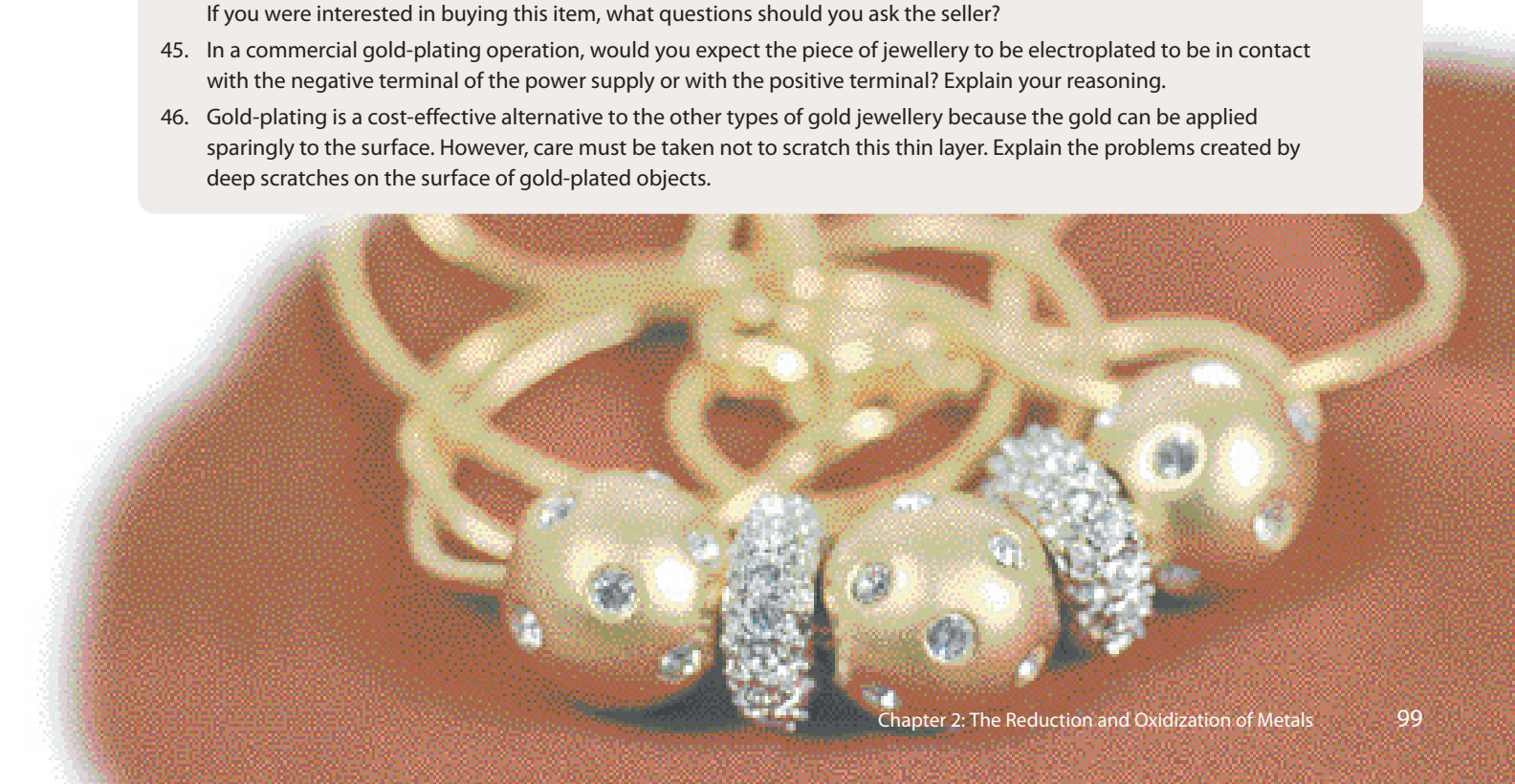
44. Consider the following description of a bracelet being sold:

    "For Sale: One gold bracelet, 15 cm long, $200."

    If you were interested in buying this item, what questions should you ask the seller?

45. In a commercial gold-plating operation, would you expect the piece of jewellery to be electroplated to be in contact with the negative terminal of the power supply or with the positive terminal? Explain your reasoning.

46. Gold-plating is a cost-effective alternative to the other types of gold jewellery because the gold can be applied sparingly to the surface. However, care must be taken not to scratch this thin layer. Explain the problems created by deep scratches on the surface of gold-plated objects.



Other Uses for Electrolytic Cells

Refining Metals

Recall that when copper is extracted from its ores, blister copper is produced from molten copper sulfide. Blister copper is 97% to 99% pure copper. Although this grade of copper is fine for many applications, it is still not pure enough for use in copper wires. Copper wire must be 99.99% pure copper. Further refinement is done using an electrolytic cell.

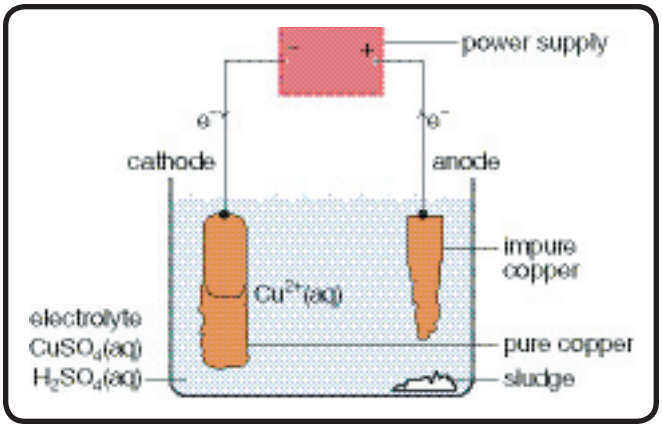


Figure A2.28: This electrolytic cell shows purifying copper.

In Figure A2.28, a very thin electrode of already pure copper is connected to the cathode. The blister copper is attached to the anode. As the copper in the blister copper is oxidized at the anode, copper ions, $Cu^{2+}(aq)$, are released and enter the solution. The free-floating, positive copper ions diffuse in the solution and are eventually attracted to the electrons at the cathode. They move toward the cathode and gain two electrons when they come into contact with it. By gaining two electrons, the copper ions are reduced to pure copper metal. Over time, the anode of impure copper shrinks while the cathode of pure copper grows.

Electrolysis

electrolysis: the decomposition of a substance by means of an electric current

Earlier in this lesson you saw how electrolytic cells can be used to divide water molecules to form hydrogen gas and oxygen gas. This process is called **electrolysis**.

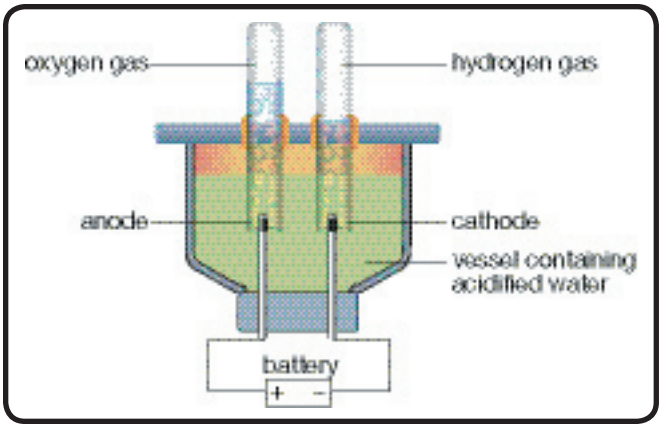


Figure A2.29: Electrolysis is actually a simple process.

In Figure A2.29, the oxygen in water molecules loses electrons at the anode to become oxygen gas, $O_2(g)$. At the same time, hydrogen in water molecules gain electrons at the cathode to become hydrogen gas, $H_2(g)$. The overall equation for this process is

$$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$$

Producing Non-Metals

Electrolytic cells are not limited to purifying only metals, they can also be used to produce non-metals.

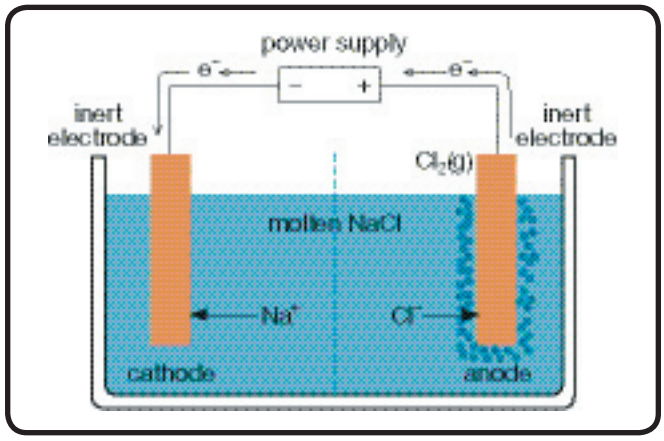


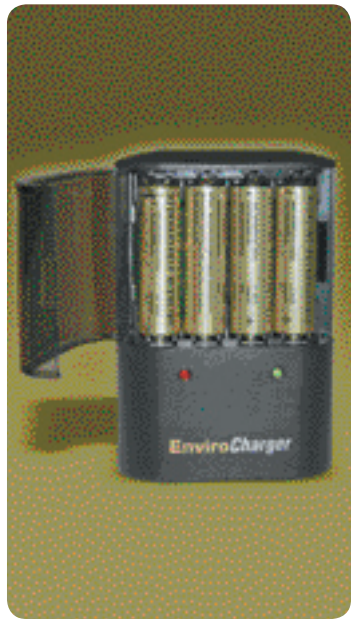
Figure A2.30: This diagram shows how an electrolytic cell produces non-metals.

In Figure A2.30, the chloride ions have electrons taken away from them at the anode to make chlorine gas. Meanwhile, the sodium ions are reduced at the cathode to produce sodium metal. Both chlorine gas and sodium metal have a large variety of industrial uses.

Chlorine is used to kill micro-organisms in both drinking water and waste-water treatment. Sodium is used as a reducing agent in refining metals like titanium.

Rechargeable Voltaic Cells

A rechargeable voltaic cell functions as an electrolytic cell when it is recharging. As mentioned earlier, a voltaic cell (or commercial cell) contains reactants that spontaneously undergo oxidation and reduction. When a cell no longer produces energy, the reactants need to be re-made. When you recharge one of these cells, you use an electric current to force the oxidation and reduction of the contents in the cell to reproduce the original reactants.



2.5 Summary

Non-spontaneous reactions require electrical energy in order for a reaction to occur. Electrolytic cells make use of non-spontaneous oxidation and reduction reactions. Electroplating is a process where you reduce metal atoms onto an object acting as an electrode. This process will give that object an outer protective layer consisting of another metal. One example is the Canadian penny. Since 1997, this coin has been made with a small percentage of copper plated over less-expensive metals. Electrolytic cells are also used to purify metals from their ores and to remove elements from compounds to produce gases.

2.5 Questions

Knowledge

1. Define the following terms.

- **a.** electrolytic cell
- **b.** electroplating
- **c.** electrolysis

2. Outline the similarities and differences between an electrolytic cell and a voltaic cell.

3. Explain the benefits of electroplating one metal with another metal.

Applying Concepts

4. Design an electrolytic cell that uses silver metal as one of the electrodes to plate a house key with silver. Be certain to include a diagram with your design that has the following components:

- electrolyte
- cathode
- anode
- loss of electrons
- gain of electrons
- negative terminal
- positive terminal
- electron flow
- products of the electrolytic cell
- power source
- oxidation half-reaction
- reduction half-reaction

5. Explain how you can purify a metal from its ore with an electrolytic cell.

6. Explain the difference between regular and rechargeable batteries.

7. Electrolysis uses an electrolytic cell to break down water molecules to form oxygen gas and hydrogen gas.

- **a.** Draw and label the important structures and products of an electrolytic cell that will complete the electrolysis of water.
- **b.** Explain why it is necessary to have an ionic compound dissolved in the water of the cell.
- **c.** Use the overall equation of electrolysis to explain how this process supports the idea that water is made up of two hydrogen atoms and one oxygen atom.

Chapter 2 Summary

In this chapter you used both balanced chemical equations and redox half-reactions to describe a variety of chemical reactions involving metals. Some of the first people on Earth to use metals were the ancient ancestors of the First Nations people in Canada. Copper artifacts thousands of years old were preserved by the layers of green corrosion on their surface.

To produce pure metals, modern mining and refining techniques reverse the corrosion process by breaking the chemical bonds within the ionic compounds found in ores. Since large quantities of ore are reduced to small amounts of pure metals, this process is called reduction. A thorough knowledge of reduction and oxidation enabled you to use the activity series for metals and metal ions to understand why gold's properties make it ideally suited for a wide variety of applications—from jewellery to microprocessors. Applications also extended to the electrochemistry of voltaic cells, batteries, and electrolytic cells.

The restoration of the '69 Chevelle can now be seen in a whole new light—it's a great application of redox chemistry. In the next chapter you will find out how fuel is made for vehicles like the '69 Chevelle.

Summarize Your Learning

This chapter explored many chemical processes that involve oxidation and reduction. At the heart of these processes is the gain and loss of electrons. You will have a much easier time recalling the application of information you learned if you take some time to organize it into some sort of pattern. Now that you have come to the end of Chapter 2, this is an appropriate time to focus on the patterns within the things you have learned.

Since the pattern has to be in a meaningful form to you, there are some options about how you can create this summary. Each of the following options is described in "Summarize Your Learning Activities" on pages 552 and 553.

Option 1: Draw a concept map or a web diagram.	Option 2: Create a point-form summary.	Option 3: Write a story using key terms and concepts.	Option 4: Create a colourful poster.	Option 5: Build a model.	Option 6: Write a script for a skit (a mock news report).

Chapter 2 Review Questions

Knowledge

1. For each of the following reactions, state whether oxidation or reduction will occur, determine the number of electrons gained or lost, and write a balanced half-reaction.

a. $Sn^{4+}(aq) \rightarrow Sn^{2+}(aq)$

b. $Na^{+}(aq) \rightarrow Na(s)$

c. $S(s) \rightarrow S^{2-}(aq)$

d. $2\ F^{-}(g) \rightarrow F_2(aq)$

e. $As(s) \rightarrow As^{3-}(aq)$

f. Gold atoms convert into gold ions.

g. Nitride ions convert into nitrogen gas.

2. Using the activity series, write the oxidation half-reaction that describes each of the following changes.

a. An atom of lithium reacts to form a lithium ion.

b. An atom of copper reacts to form a copper(II) ion.

3. Examine the following balanced chemical equations:

- $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
- $2\ Ni(s) + O_2(g) \rightarrow 2\ NiO(s)$
- $Ag_2S(s) + Ca(s) \rightarrow CaS(s) + 2\ Ag(s)$

a. Identify the chemical substances being oxidized.

b. Identify the chemical substances being reduced.

c. Identify any ions that do not undergo oxidation or reduction during the reaction (spectators).

4. Refer to the balanced chemical equations in question 3.

a. Determine the number of electrons gained by each atom or ion.

b. Determine the number of electrons lost by each atom or ion.

5. Determine whether the following substances could undergo oxidation, reduction, or both.

a. lithium atom, Li(s)

b. hydride ion, $H^{-}(aq)$

Applying Concepts

6. If you place a strip of aluminium metal into hydrochloric acid, you will obtain hydrogen gas. The balanced chemical equation that describes this process is

$$2\ Al(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$$

a. State the chemical substance that is gaining electrons. Provide a reason for your choice.

b. State the chemical substance that is losing electrons. Provide a reason for your choice.

c. State the chemical substance that is neither gaining nor losing electrons. Provide a reason for your choice.

d. State the atom or ion that is being oxidized.

e. How many moles of aluminium metal are required to make 300 mol of hydrogen gas?

f. How many moles of hydrochloric acid are required to make 300 mol of hydrogen gas?

7. Balance the following reactions.

a. $HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$

b. $Pb(NO_3)_2(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + Pb(s)$

c. $AgNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$

d. $AuCl_3(aq) + Zn(s) \rightarrow ZnCl_2(aq) + Au(s)$

8. Aspirin, $C_9H_8O_4(s)$, is easily made by reacting salicylic acid, $C_7H_6O_3(aq)$, and acetic anhydride, $C_4H_6O_3(s)$. This is described by the chemical reaction

$$2\ C_7H_6O_3(aq) + C_4H_6O_3(s) \rightarrow 2\ C_9H_8O_4(s) + H_2O(l)$$

You have 3.56 mol of acetic anhydride.

a. How many moles of aspirin could you produce?

b. How many moles of water will this reaction produce?

c. How many moles of salicylic acid will you need?

9. Cement is primarily made up of a substance called quicklime, CaO(s). Quicklime is created by using heat to decompose limestone, $CaCO_3(s)$. A by-product of this reaction is carbon dioxide, $CO_2(g)$. The balanced chemical reaction that describes this process is

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

In the process of making quicklime, a factory releases 7.13×10^5 mol of carbon dioxide into the air every day.

a. How many moles of quicklime is the factory producing every day?

b. How many moles of limestone is the factory using every day?

c. Explain how your answer makes sense by describing what is occurring to the limestone at the atomic scale.

Use the following information to answer questions 10 to 13.

The process of producing copper metal from ores containing copper involves a step in which air is blown over molten copper(I) sulfide in a conversion furnace. The product that emerges from this furnace is called blister copper, because its surface is blistered by the escaping sulfur dioxide gases as the sulfur solidifies. The equations describing the reactions that occur as air is blown over the molten copper(I) sulfide to produce pure copper are as follows:

Reaction 1: $2\ Cu_2S(l) + 3\ O_2(g) \rightarrow 2\ Cu_2O(l) + 2\ SO_2(g)$

Reaction 2: $2\ Cu_2O(l) + Cu_2S(l) \rightarrow 6\ Cu(l) + SO_2(g)$

10. Consider each substance described in Reactions 1 and 2. Classify each substance as being an ionic compound, a molecular compound, or a pure metal.

11. Every 1000 kg of ore mined from Kidd Creek Mine in Ontario typically contains about 18 kg of copper and 58 g of silver.

a. Determine the percentage of the ore that contains copper.

b. Determine the concentration of the silver in the ore in parts per million.

c. Explain the statement, "Percentage and parts per million are actually very similar methods for communicating parts of a whole. In fact, percentage could also be called parts per hundred to help people see the similarities."

12. A copper refining operation uses about 34.4 mol of oxygen every second in the refining of copper(I) sulfide.

a. Determine the number of moles of copper(I) sulfide required for this reaction every second.

b. Determine the number of moles of copper(I) oxide produced by this reaction every second.

13. Sulfur dioxide has been shown to cause a number of health and environmental problems. The mining industry has responded by reducing their emissions of sulfur dioxide. This is done by capturing some of the sulfur dioxide produced and converting it into sulfuric acid. Despite these efforts, in Canada about 40% of all sulfur dioxide emissions come from the mineral sector. Use the Internet to determine any health and environmental problems caused by the release of sulfur dioxide.

14. A small coffee cup has a volume of 250 mL. The density of gold is 19.4 g/mL.

a. Use the density of gold as a conversion factor to determine the total mass of the fine grains of gold that could fill a coffee cup.

b. Use the Internet to find the current world price for a gram of gold. Use your answer from question 14.a. to calculate the current value (in Canadian dollars) of a small coffee cup filled with fine grains of gold.

c. As indicated by your answer to question 14.a., gold is a very dense substance. Explain how this property can be used to separate particles of gold from small grains of sand and other minerals when streambed deposits are swirled with water in a shallow container. This process is called panning for gold.

15. Describe how an activity series could be used to

a. determine the reactivity of various metals

b. determine the reactivity of various metal ions

c. determine whether a particular combination of a metal and a solution containing a metal ion would spontaneously react

16. Use the activity series for metals and metal ions to complete the following table. Indicate whether a spontaneous reaction or a non-spontaneous reaction will occur with each combination.

Metal	Metal Ion		
	$Al^{3+}(aq)$	$Zn^{2+}(aq)$	$Sn^{2+}(aq)$
Al(s)			
Zn(s)			
Sn(s)			

17. Use your knowledge of reduction and oxidation to explain what occurs to a metal when it corrodes and the techniques that protect metals from corrosion.

18. Draw a voltaic cell that consists of nickel and magnesium electrodes, each within a solution of its metal ion. Label the cathode, anode, positive and negative electrodes, electrolytes, flow of electrons through the external circuit, and flow of ions through the salt bridge. Assume the salt bridge contains a solution of potassium nitrate, $KNO_3(aq)$.

19. A voltaic cell is described by the following cell notation:

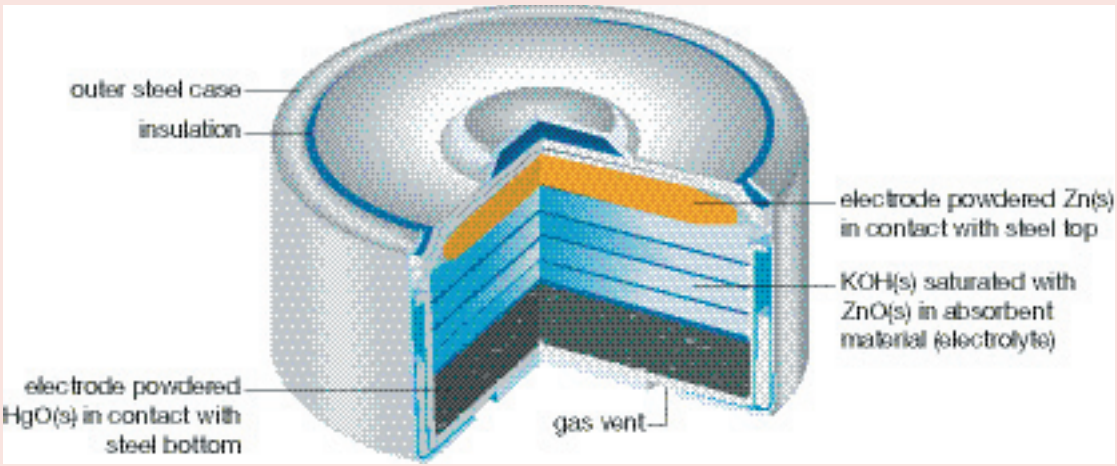
$Al(s)|Al^{3+}(aq)||Fe^{2+}(aq)|Fe(s)$

Draw a detailed diagram of this voltaic cell. Include labels for the direction of the flow of electrons, anions, and cations within the cell. Assume the salt bridge contains a solution of potassium nitrate, $KNO_3(aq)$.

20. Compare the voltaic cells in questions 18 and 19. Identify which voltaic cell would produce the higher output on the voltmeter. Concisely explain your reasoning.

21. Devices like watches, pacemakers, and hearing aids require cells that are very small. In these applications, a miniature mercury button cell is often used.

Mercury Button (Miniature) Cell


outer steel case
insulation
electrode powdered Zn(s) in contact with steel top
KOH(s) saturated with ZnO(s) in absorbent material (electrolyte)
electrode powdered HgO(s) in contact with steel bottom
gas vent

Although the chemical reactions within these cells are complex, they can still be categorized as oxidation and reduction:

Reaction 1: $Zn(s) + 2\ OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$
Reaction 2: $HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2\ OH^-(aq)$

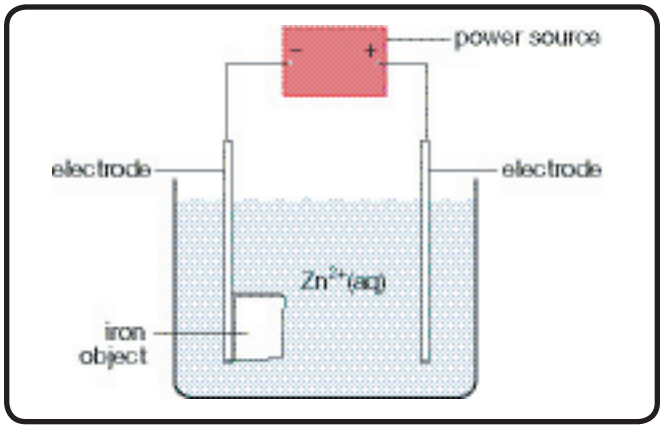
a. Classify Reaction 1 as being either an oxidation or a reduction reaction. Support your answer.
b. Is the powdered zinc in contact with the steel top acting as the anode or the cathode in this cell?
c. Classify Reaction 2 as being either an oxidation or a reduction reaction. Support your answer.
d. Is the powdered HgO(s) in contact with the steel bottom acting as the anode or the cathode in this cell?
e. Would electrons leave the top or the bottom of this cell to flow through an external circuit.

22. Zinc is electroplated over iron metal to prevent the corrosion of iron nails. This process is called galvanizing. Explain how the zinc acts to protect the iron.

23. Refer to the diagram on the right.

a. Identify the type of cell depicted as either voltaic or electrolytic.

b. Describe the importance of the power source to the chemical change that occurs in the cell.

c. Determine the direction of electron flow in this cell.

d. Identify the half-reaction that occurs at the cathode of this cell.